Forest Site Management Section
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SILVICULTURE NOTE 24

A METHOD TO CHECK THE PERFORMANCE OF A GROWTH INTERCEPT MODEL

1 Introduction

This note provides an overview of a method to check the performance of a growth intercept model. Forest managers—not sampling experts—are the target audience. The objective of this note is to introduce foresters to a type of project that can be undertaken with the assistance of an inventory specialist/statistician.

There are many ways to check the performance of a growth intercept model. Here we describe one simple method that has been used successfully to look for bias in the site index estimates of:

1. the coastal Douglas-fir growth intercept model in logged and regenerated stands in TFL 45 (J.S. Thrower and Associates Ltd. 1999)
2. the interior spruce growth intercept model in logged and regenerated stands in a portion of the Prince George Forest District.

2 Background

In British Columbia, the growth intercept (GI) method is widely used to estimate site index (SI) in young stands. For example, the GI method was used to develop province-wide adjustments to inventory file site indices for old-growth Douglas-fir, lodgepole pine, and interior spruce stands (Nussbaum 1998).

To construct a GI model, site trees at least 50 years old are sampled—generally in stands of natural origin. Using stem analysis, site tree height growth over time is observed and early heights and ages are related to final site index (for an example, see Nigh 1998).

An application bias could cause a GI model to produce biased estimates of SI. Application bias may occur if the shape of height growth curves in the population in which the GI model is applied differ from the shape observed in the sample used to construct the GI model (Figure 1). This situation could arise if harvesting, site preparation, or regeneration practices alter top height growth patterns from those that were present in the GI model fit data set (B.C. Ministry of Forests 1998).

Because application bias and other sources of bias are theoretically possible, BC's GI models are being tested against both experimental data and random sampling data (Nemec 1999; Nigh and Martin [in preparation]). Due to the importance of GI models to forest management in BC, this document describes a method that can provide forest managers with a measure of confidence in the models, as well as a means to assess the risk and uncertainty associated with using them.

3 Description of the Method

There are three phases to a project to check the performance of a GI model:

1. preliminary organization
2. field sampling
3. data analysis.

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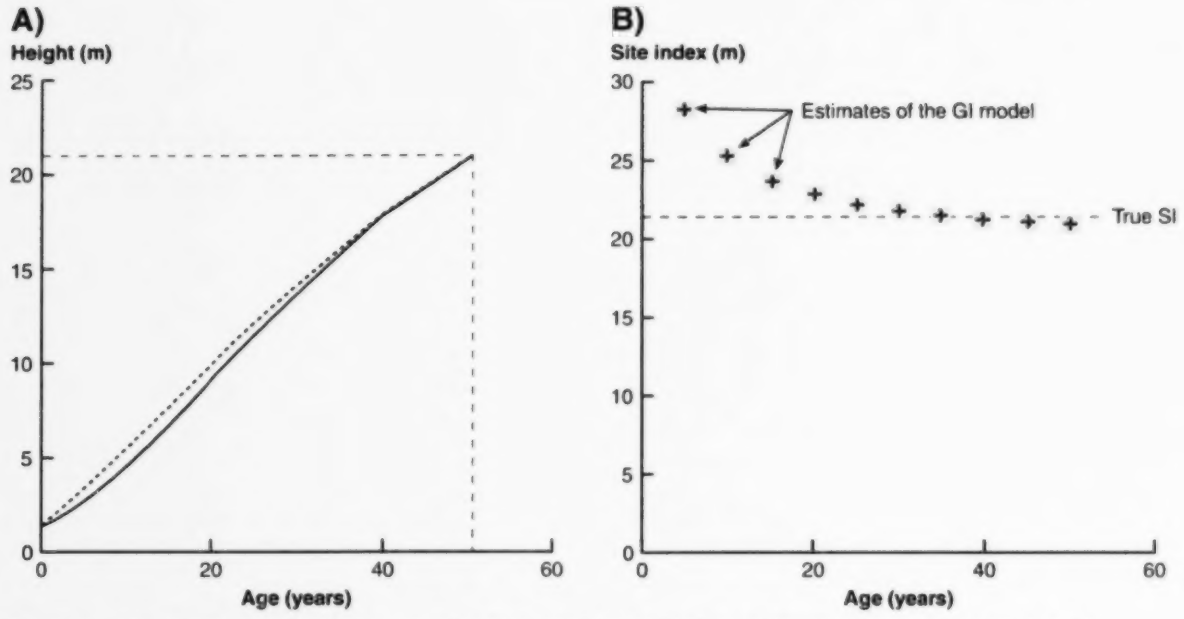

Figure 1. Hypothetical example of application bias. A) On SI of 21 m, the GI model assumes that site height develops along the solid line while a local population of stands develops along the dashed line. B) Due to this deviation from the expected height growth shape, when the GI model is used in the local population, its SI estimates are biased at young ages.

4 Phase I – Preliminary Organization

4.1 Develop a work plan

The project should be guided by a thorough plan. This plan should:

- state the objective of the study
- define the population
- describe how samples will be selected
- describe the sample plot layout
- specify the measurements that will be taken and the required precision
- present a schedule for the work
- indicate the desired sample size
- describe the proposed data compilation and analysis.

Most of these elements are described in more detail below. Many aspects of the sample design follow closely the design for ground sampling in BC's new provincial Vegetation Resources Inventory (B.C. Ministry of Forests 1997).

4.2 State the objective

The objective of the method outlined in this report is to assess bias in the SI estimates of a GI model when applied to a specific population. Bias is evaluated over site tree age (and sometimes, other variables). The method is designed to allow an assessment of the statistical reliability of the results.

4.3 Define the population

The population is defined as site trees of the target species in polygons meeting specified criteria in the management unit. Generally, these criteria are polygon leading species, land ownership class and stand establishment date. These criteria may also include treatment, history, or origin, but frequently there is inadequate information on record to include these variables.

A site tree is the largest dbh tree of the target species in a 0.01 ha plot. In addition, it must be:

1. free from stem damage
2. in the dominant or codominant crown class
3. free of suppression and repression
4. healthy.[1]

[1] See the top height definition on the Forest Productivity Council of British Columbia web site: <http://www.forestproductivity.gov.bc.ca/Standards/topheight/top_height.htm>.

So for a particular project, for example, the population may be defined as Douglas-fir site trees in logged and regenerated Fd leading polygons that have not been fertilized within a specific TFL, with establishment dates 1965–1975.

4.4 Prepare a list of polygons

To prepare the list of polygons that are candidates for sampling, the attribute file for every map sheet in the management unit must be obtained. Every polygon which meets the criteria is identified. The list of candidate polygons (along with their attributes and polygon area) is sorted by map sheet and site index.

4.5 Select polygons to sample

From the sorted list of candidate polygons, some are selected for sampling using a process of systematic selection with multiple random starts and selection probability proportional to polygon area. The documentation for BC's new provincial Vegetation Resources Inventory provides an excellent discussion of this procedure (B.C. Ministry of Forests 1997). Twice as many sample points as needed are selected. The extras are used to create a replacement list for use in the event that some of the selected points are found to be unsuitable when visited in the field (see **5 Phase II – Field Sampling**).

4.6 Select sample location within polygon

Air photos and forest cover maps for the selected polygons must be obtained. These are used to navigate to the selected polygons and to select a sample location inside the polygon. Typically, the sample location is chosen at random from the intersection points of a 100 × 100 m grid that covers the polygon.

4.7 Sample size

The variability observed in previous projects suggests that 30 samples are required to detect a bias of 2 m in estimated SI at the 95% confidence level, at breast height age five years.

5 Phase II – Field Sampling

At the sample point inside the polygon, a sample cluster is established. The cluster consists of five 0.01 ha sub-plots: one centred on the sample point and the remainder 25 m from the sample point in each cardinal direction (Figure 2). In each sub-plot, the field crew identify the largest dbh tree of the target species. If it meets the site tree definition (see **4.3 Define the population**), the tree is cut down. Starting at the top of the tree, the field crew measure the distance from the terminal to each annual whorl (Figure 3). Periodically, the tree stem is cut and annual rings counted to confirm the measurements. Measurement continues down the stem to the whorl below breast height. Total tree height and breast height age are measured. Destructive sampling procedures are described by the B.C. Forest Productivity Council. (1998).

If the largest dbh tree of the target species is not a site tree, or if the sub-plot does not contain any trees of the target species, then it is a null sub-plot.

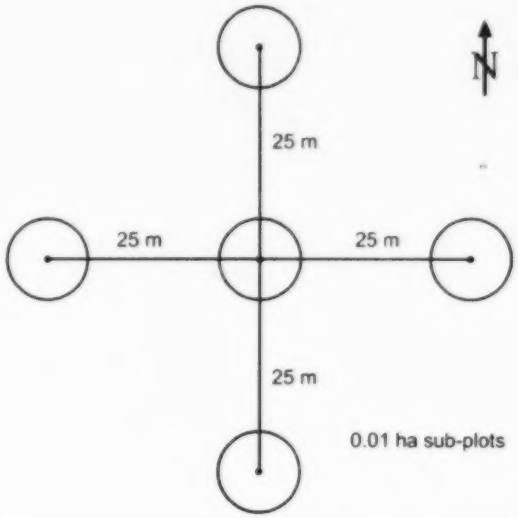

Figure 2. The layout of sub-plots in the cluster sample.

Annual Whorl	Distance from terminal (cm)
0	0
1	37
2	62
3	99
4	131
.	.
.	.
.	.

Figure 3. The measurement of a site tree.

6 Phase III – Data Analysis

The data that are collected can be compiled and analyzed many different ways. The principal analysis proceeds as follows:

1. For each sample cluster, average the site tree heights at each bh age. Compute the GI estimate of SI for each sample cluster at each bh age using these average heights.
2. For each site tree, obtain the best current estimate of SI from current tree height and bh age. Average the current SI estimates of each site tree in the sample cluster. Take this average as the "true" SI for the sample cluster.
3. For each sample cluster, at each bh age compute the difference between estimated SI and "true" SI.
4. Pool the data from all sample clusters and compute the mean of the SI differences at each bh age and the 95% confidence interval on the mean.
5. Plot the mean difference and the confidence intervals over time (Figure 4). Interpret this graph to assess the performance of the GI model in the population.

For an example, see J.S. Thrower and Associates Ltd. (1999).

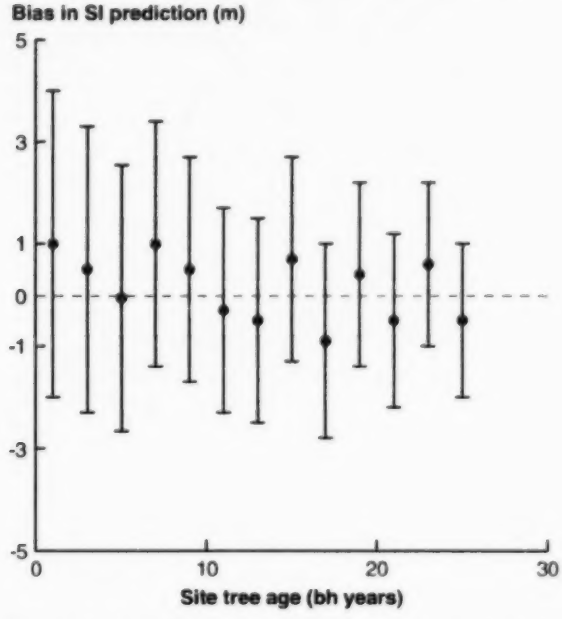

Figure 4. Hypothetical example of sample results showing mean and 95% confidence intervals of site index bias over site tree age.

7 Other Project Management Issues

7.1 Quality assurance

To obtain reliable results, field crews must be well trained. After field crews have established a few plots, a careful check of their procedures is recommended. Field crews will do a better job if they are using field cards or a data logger set up specifically for the data that they are collecting.

7.2 Assistance of specialists

To develop the sample plan, the assistance of an inventory specialist will be required. The Site Productivity Working Group (SPWG) would like to know about the project. Specialists on the SPWG will be happy to assist with the project. The SPWG web site provides contact information and relevant publications: <http://www.for.gov.bc.ca/resinv/G&Y/Projects/spwg/index.htm>.

7.3 Permission to cut trees

Permission must be obtained to cut trees on Crown forest land. The district manager may choose to grant permission through Section 52 of the *Forest Practices Code of British Columbia Act*.

7.4 Costs and schedule

A study involving 30 samples takes approximately:

a) 20 person-days in preliminary organization

b) 70 person-days in field sampling

c) 30 person-days in data analysis and report writing.

In the field, sampling crews generally achieve production rates of one cluster sample per two-person crew per day.

8 Possible Refinements

Many refinements and modifications to the simple method described in this document are possible.

8.1 Site trees rare

In some populations, site trees are infrequent and it may be necessary to add to the number of sub-plots in the cluster, and/or identify alternative sample points within the polygon that can be visited if the first cluster fails to yield site trees.

8.2 Pre-stratification

In some studies, it may be desirable to identify two (or more) strata, sample from each stratum, and compare SI bias between strata.

8.3 Recording additional data

It may be desirable to collect additional mensuration and site data at each sample. These data can be used to post-stratify the samples and identify differences in SI bias between groups. This analysis may help identify sub-populations in which the GI is performing poorly (Figure 5).

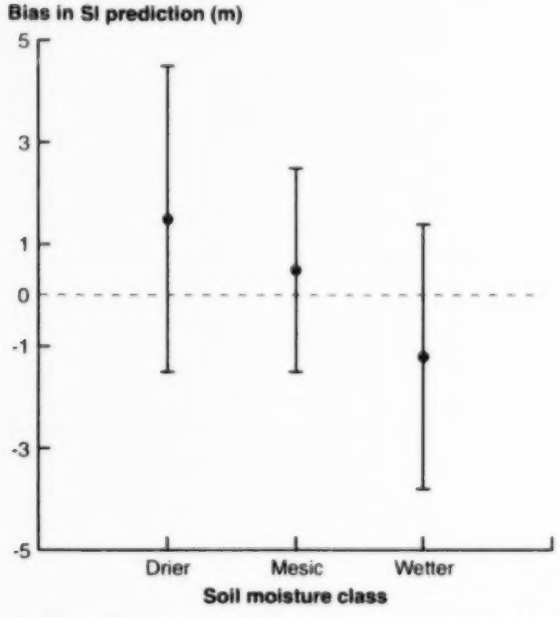

Figure 5. Hypothetical example of a comparison of site index bias between three soil moisture classes.

8.4 Non-destructive sampling

For some species of site trees, non-destructive sampling may be possible. A telescoping height pole can be used to measure the first 10–15 years growth above breast height if branch whorls and other features clearly indicate previous height growth (Figure 6).

8.5 Weighting observations

If the number of sub-plots sampled per cluster varies, weight each sample during compilation and statistical analysis to reflect the number of sub-plots in the sample.

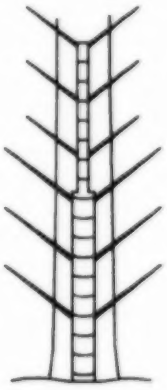

Figure 6. In some cases, annual height for the first 10–15 years growth above breast height may be measured with a telescoping height pole.

8.6 Additional analyses

Many additional analyses are possible. Advanced analyses may recognize the correlation of repeated measurements on the site trees.

9 Acknowledgements

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